



Marsbound! Mission to the Red Planet

Grades: 6-12

Prep Time: ~1 hour

Lesson Time: 3 45-minute sessions



WHAT STUDENTS DO: Design a Mission to Mars.

Curious about how engineers design a Mars mission? In this fun, interactive card game, students experience the fundamentals of the engineering design process, with a hands-on, critical-thinking, authentic approach. Using collaboration and problem-solving skills, they develop a mission that meets constraints (budget, mass, power) and criteria (significant science return). This activity can introduce many activities in technology education, including robotics and rocketry. In this collection, it deepens skills from Lesson 6 and builds them for Lesson 12.

NRC CORE & COMPONENT QUESTIONS

HOW DO ENGINEERS SOLVE PROBLEMS?

NRC Core Question: ETS1: Engineering Design

What Is a Design for? What are the criteria and constraints of a successful solution?

NRC ETS1.A: Defining & Delimiting an Engineering Problem

What Is the Process for Developing Potential Design Solutions?

NRC ETS1.B: Developing Possible Solutions

INSTRUCTIONAL OBJECTIVES

Students will be able

IO1: to design a technological solution (mission) by making tradeoffs within constraints



1.0 About This Activity

This activity is part of the Imagine Mars Project, co-sponsored by NASA and the National Endowment for the Arts (NEA). The Imagine Mars Project is a hands-on, STEM-based project that asks students to work with NASA scientists and engineers to imagine and to design a community on Mars using science and technology, then express their ideas through the arts and humanities, integrating 21st Century skills. The Imagine Mars Project enables students to explore their own community and decide which arts-related, scientific, technological, and cultural elements will be important on Mars. Then, they develop their concepts relating to a future Mars community from an interdisciplinary perspective of the arts, sciences, and technology. <http://imaginemars.jpl.nasa.gov>

The Imagine Mars lessons leverage *A Taxonomy for Learning, Teaching, and Assessing* by Anderson and Krathwohl (2001) (see *Section 4* and *Teacher Guide* at the end of this document). This taxonomy provides a framework to help organize and align learning objectives, activities, and assessments. The taxonomy has two dimensions. The first dimension, cognitive process, provides categories for classifying lesson objectives along a continuum, at increasingly higher levels of thinking; these verbs allow educators to align their instructional objectives and assessments of learning outcomes to an appropriate level in the framework in order to build and support student cognitive processes. The second dimension, knowledge, allows educators to place objectives along a scale from concrete to abstract. By employing Anderson and Krathwohl's (2001) taxonomy, educators can better understand the construction of instructional objectives and learning outcomes in terms of the types of student knowledge and cognitive processes they intend to support. All activities provide a mapping to this taxonomy in the Teacher Guide (at the end of this lesson), which carries additional educator resources. Combined with the aforementioned taxonomy, the lesson design also draws upon Miller, Linn, and Gronlund's (2009) methods for (a) constructing a general, overarching, instructional objective with specific, supporting, and measurable learning outcomes that help assure the instructional objective is met, and (b) appropriately assessing student performance in the intended learning-outcome areas through rubrics and other measures. Construction of rubrics also draws upon Lanz's (2004) guidance, designed to measure science achievement.

How Students Learn: Science in the Classroom (Donovan & Bransford, 2005) advocates the use of a research-based instructional model for improving students' grasp of central science concepts. Based on conceptual-change theory in science education, the 5E Instructional Model (BSCS, 2006) includes five steps for teaching and learning: Engage, Explore, Explain, Elaborate, and Evaluate. The Engage stage is used like a traditional warm-up to pique student curiosity, interest, and other motivation-related behaviors and to assess students' prior knowledge. The Explore step allows students to deepen their understanding and challenges existing preconceptions and misconceptions, offering alternative explanations that help them form new schemata. In Explain, students communicate what they have learned, illustrating initial conceptual change. The Elaborate phase gives students the opportunity to apply their newfound knowledge to novel situations and supports the reinforcement of new schemata or its transfer. Finally, the Evaluate stage serves as a time for students' own formative assessment, as well as for educators' diagnosis of areas of confusion and differentiation of further instruction. This five-part sequence is the organizing tool for the Imagine Mars instructional series. The 5E stages can be cyclical and iterative.



2.0 Materials

Required Materials

Please supply:

- Equipment **Cards** – 1 per team
- Design **Mat** – 1 per team
 - These can be downloaded from
http://marsed.asu.edu/lesson_plans/marsbound

Please Print:

From Student Guide

- | | |
|---|-----------------|
| (A) Student Instruction Sheet | – 1 per student |
| (B) Student Pre-Ideas Worksheet | – 1 per student |
| (C) Activity 1 Fact Sheet: Mars Exploration Science Goals | – 1 per student |
| (D) Activity 1 Science Objectives Worksheets | – 1 per team |
| (E) Activity 2 Identify Your Mission Goals Worksheets | – 1 per team |
| (F) Activity 3 Building Your Spacecraft Fact Sheet | – 1 per team |
| (G) Activity 4 Spacecraft Design Log | – 1 per team |
| (H) Activity 4 Engineering Constraints | – 1 per student |
| (I) Activity 5: Identifying Constraints in Other Missions | – 1 per student |
| (J) Student Post-Ideas Worksheet | – 1 per student |
| (K) Comparing Rover Missions Fact Sheet (optional) | – 1 per team |

Optional Materials

From Teacher Guide

- (L) “Marsbound” Assessment Rubrics
- (M) Placement of Instructional Objective and Learning Outcomes in Taxonomy



3.0 Vocabulary

Engineering Constraints	limits placed on your mission by the hardware you use to accomplish the mission.
Models	a simulation that helps explain natural and human-made systems and shows possible flaws
Predict	a declaration about what will happen based on reason and knowledge
Relative Distance	how far away objects are when compared to one another
Relative Size	how large objects are when compared to one another
Relationship	a connection between two objects
Scale	a comparative relation between objects such as size or distance

4.0 Instructional Objectives, Learning Outcomes, & Standards

Instructional objectives, standards, and learning outcomes are aligned with the National Research Council's *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas*, which serves as a basis for upcoming "Next-generation Science Standards." Current National Science Education Standards (NSES) and other relevant standards are listed for now, but will be updated when the new standards are available.

The following chart provides details on alignment among the core and component NRC questions, instructional objectives, learning outcomes, and educational standards.

- Your **instructional objectives (IO)** for this lesson align with the NRC Framework and education standards.
- You will know that you have achieved these instructional objectives if students demonstrate the related **learning outcomes (LO)**.
- You will know the level to which your students have achieved the learning outcomes by using the suggested **rubrics** (see Teacher Guide at the end of this lesson).

Quick View of Standards Alignment:

The Teacher Guide at the end of this lesson provides full details of standards alignment, rubrics, and the way in which instructional objectives, learning outcomes, 5E activity procedures, and assessments were derived through, and align with, Anderson and Krathwohl's (2001) taxonomy of knowledge and cognitive process types. For convenience, a quick view follows:



WHAT IS THE UNIVERSE & WHAT IS EARTH'S PLACE IN IT?

NRC Core Question: ESS1: Earth's Place in the Universe

What are the predictable patterns caused by Earth's movement in the solar system?

NRC ESS1.B: Earth & the Solar System

Instructional Objective <i>Students will be able</i>	Learning Outcomes <i>Students will demonstrate the measurable abilities</i>	Standards <i>Students will address</i>	
IO1: to design a technological solution (mission) by making tradeoffs within constraints	LO1a. to differentiate between the purposes of scientific inquiry and technological design LO1b. to analyze requirements and constraints in a design task LO1c. to construct an appropriate science question (problem) requiring a technological design LO1d. to generate an appropriate technological solution within constraints LO1e. to explain the complex relationship between science and engineering design	NSES (E): SCIENCE & Technology: Abilities of Technological Design Grades 5-8: E1a NSES (E): SCIENCE & Technology: Understandings about Science & Technology Grades 5-8: E2a, E2c, E2d, E2e	Rubrics in Teacher Guide

This activity also meets the following standards:

21st Century Skills

- Creativity and Innovation
- Collaboration
- Social and Cross-Cultural Skills
- Productivity and Accountability

National Education Technology Standards (NETS-S)

- Creativity and Innovation
- Communication and Collaboration
- Critical Thinking, Problem Solving, and Decision Making




5.0 Procedure

PREPARATION (~10 minutes)

A. PRINT THE FOLLOWING:

- Equipment **Cards** – 1 per team
- Design **Mat** – 1 per team
- Student **Worksheets (A-K)** – 1 per student

 **Teacher Tip:** If you have printed the game board and cards from the website in black and white, ask your students to color the cards for you using a marker or colored pencil prior to laminating.

Color Key		
Game Board System	Color	Coordinating Card #s
Launch System	Red	1-6
Power System	Orange	7-12
Science Instruments	Blue	13-25
Mobility System	Fuchsia	26-27
Mechanical System	Yellow	28-30
Entry, Descent, & Landing System	White	31-35
Computer System	Purple	36-38
Communications System	Aqua	39-41
Special Events	Green	42-47

STEP 1: ENGAGE

Set up the Scenario of Mission Planning

A. Read the following:

Imagine that today, your school principal announces that you will be working on a new, very complex school project, a project that no one has ever done before. This project will be the single most important task you have ever been asked to complete thus far in your life. This project will be a group project, and you will be working with some people you know and others you don't know. Everyone in your entire group will need to complete the group project successfully or no one will pass. In fact, the project is so important, you will be working on it in every one of your classes, during an afterschool program, and as homework. You will probably be working on it at least 12+ hours a day and during many weeks; you will work through the weekend, too! You will have just 2 years to complete the project. The project is so complex and difficult, that you will have to revise and rewrite the plans for the project constantly. When the project deadline arrives, the group will have to show the completed project to the school, principal and, oh yes, all the news stations in the world will be there as well. You will have no extensions on the deadline. No pressure, but everyone is counting on you!




NASA mission planners, engineers, and scientists go through much the same process when designing and building space missions to Mars and other destinations. Many times, they are faced with tasks that have never been tried before. Imagine that they have spent 2 years of their lives, 12+ hours a day, planning, building, planning, testing, retesting, re-planning, re-building, re-testing, packaging, shipping, unpacking, testing, and re-testing, all in an attempt to do everything in their power to ensure their mission makes it to the surface of Mars.

- B.** Explain they will be playing a card game to design a mission to Mars. As part of “qualifying” for the mission planning, ask students to complete the Pre-Ideas.

This survey will help to establish their current understandings of mission planning and engineering constraints. Students will use this information during the Post-Ideas as part of their individual assessments.

- C.** Hand Out:

- **Marsbound! Student Guide (Worksheets A-K)** – 1 per student
- **Equipment Cards** – 1 per team
- **Design Mat** – 1 per team


 **Curiosity Connection Tip:** For making a connection to NASA’s Mars Rover “Curiosity,” please show your students additional video and slideshow resources at:

<http://mars.jpl.nasa.gov/participate/marsforeducators/soi/>

STEP 2: EXPLORE

Construct a Science Question Requiring a Technological Design.

A. Activity 1: The purpose of this activity is to familiarize students with national goals for the exploration of Mars, and to enable students to categorize science questions according to these goals. Discuss NASA’s four Mars Exploration Program goals and strategies with students. Working with their teams, students will categorize each question under each goal.

 **Teacher Tip:** Keep in mind that a science question (mission objective) may apply to more than one science goal. There is no one “correct” answer; it is more important that your students can justify the reasons for the categorization.

NASA’s four Mars Exploration Program goals


- Determine if life ever arose on Mars.** All life, as we know it, requires water to survive. In fact, on Earth we have found life wherever there is water, even in places we didn’t think life could exist, such as frozen deserts of Antarctica. Is the same thing true of Mars? Because of the low temperatures and thin atmosphere of Mars today, we know that there is currently no liquid water on the surface of the planet. But was that always true?




- ii. **Characterize the climate of Mars.** If we can understand what the climate of Mars is like today and how it changes, we will have a better idea of what the climate of Mars was like in the past. The atmosphere of Mars is mostly carbon dioxide, but two other important components are water vapor and dust. With enough information, we can begin to create a picture of the overall climate of Mars now and what it may have once been like.
- iii. **Characterize the geology of Mars.** Rocks and minerals on the surface of Mars can tell us a great deal about a planet's past. By studying surface morphology and patterns and types of features found on the surface, we can find a permanent record of the history of Mars in its rocks.
- iv. **Prepare for human exploration.** Humans are naturally curious. No robot will ever have the flexibility of a human explorer, so someday we will want to travel to Mars ourselves to study the planet and its history directly. Because of the difficulty and the number of challenges, robotic spacecraft must pave the way for humans to follow. One important task is to study new techniques for entering the Martian atmosphere and landing on the surface. We will also need to understand the dangers humans will face on the surface of Mars.

Differentiate between a Scientific Question and a Technological Design/Solution.

- B. Activity 2:** Student teams will discuss possible science objectives among themselves. Students will also determine a technological solution by deciding whether they want to fly a lander, orbiter, or fly-by mission to Mars.

 **Teacher Tip:** Space is provided for 5 science goals, but your students will be hard-pressed to design a spacecraft (under budget) that can meet all five goals. This constraint is intentional, as it will guide them to revise their mission plan by going all the way back to the original Mission Goals page. This iterative process happens quite often in the real world as well.

 **Teacher Tip:** In preparing students to make choices on whether to use a lander, orbiter, or fly-by, you can use the **Strange New Planet** activity (Lesson 6 in this collection) for a hands-on activity about exploring new planets.


Design a Technological Solution.

- C. Activity 3:** Student teams will begin to design the actual spacecraft that they will use for their mission. To facilitate this, each typical system that could be onboard a spacecraft is presented on its own “trading card.” Students will need to read each card carefully, as the text provides clues about the uses and limitation for that particular piece of hardware.
- i. Important! Hold the **(Green) Special Events cards** until the end of the simulation.
 - ii. Students will begin the simulation by choosing a **(Red) Rocket Card and Rocket Nose Cone** (required). The rocket card will determine the **Mass Limit** for the




mission and will include the **Cost** in millions of dollars. The nose cone will be additional **Weight** and money, so students will need to record this information into their **Spacecraft Design Log**.

- iii. Students will then choose a **(Orange) Power System Card**. This card will determine the Power available during the mission.
- iv. From here, students will choose their **(Purple) Computer Systems**, **(Aqua) Communication Systems**, and **(Blue) Science Instruments** cards to achieve their science goals stated in Activity 2. These will help to increase Science Return.
- v. If students have chosen a rover or lander for their mission, rovers will need to include a **(Fuchsia) Mobility System**, and both rovers and landers will require **(White) Entry, Descent, & Landing Systems**.
- vi. The final decision will be optional **(Yellow) Mechanical Systems**. These can increase the Science Return, but should be considered last due to budget constraints.
- vii. Remind students to keep a tally in their Spacecraft Design Log to ensure they are staying within budget, power and mass.

 **Differentiation Tip:** The teacher will need to define the budget. Lower amounts make it a more challenging activity, while higher amounts make it less challenging. Starting with \$250 million is recommended as a good “average” level of difficulty for any of the missions.

- viii. When students have created a mission within budget, power, and mass, they can now select a **(Green) Special Events card**. Half of these cards are Spin-offs or advances in technology that can be commercialized. These add money to the budget. The other half of the cards is failures or cuts to the budget. These take away money from the budget. Allow students time to adjust their mission to accommodate these scenarios.

 **Teacher Tip:** Ask students to use a pencil on their Spacecraft Design Log so that they can easily erase when necessary.


- ix. The final step will be launch day. **Science Return** will establish the order of launch. Start with the highest **Science Return** and falling under budget, mass and power. Students will roll the die to determine if their mission launched successfully. The type of rocket they chose will determine the success rate. For example, the Heavy-Lift Rocket is high risk, only lifting of successfully 3 out of 6 times. If students roll a 1, 2, or 3, they lift successfully. If they roll a 4, 5, or 6, launch fails and the mission is over.



STEP 3: EXPLAIN

Analyze Constraints within a Technological Design.

- A. Activity 4:** This activity focuses on the concept of engineering constraints. Encourage students to think of everything that limited what they attempted to do with their mission. Examples would include the limited mass that can be lifted by the rocket booster available, the electrical power that is required by each system onboard, and staying within the pre-determined budget.

 **Differentiation Tip:** Ask students to consider other constraints that might limit a mission beyond what they discussed here. For example, a lander mission needs to be able to land safely in the terrain chosen to meet the science goals. After a little research, your students may realize that it is impossible to land safely in some kinds of terrain (such as mountains or the slopes of a volcano).

- B.** Ask students to share their constraints and accommodations with the class. The goal of this sharing process is to have the students listen critically to their peers' explanations, explain their own solutions, and question others' explanations.

After class sharing, take a few minutes to discuss and reaffirm some of the items they may have mentioned and highlight those missed (see bulleted list below.)

- **Size and Mass:** Some engineering constraints are due to the strength of the rocket you use to send your spacecraft to Mars. To send every instrument to Mars would require a rocket so large that it doesn't even exist.
- **Budget:** The United States Congress sets the budget, the total amount of money available to spend for each NASA mission. NASA must therefore, design missions to achieve as many science goals as possible, while still staying within budget. Bigger rocket boosters can carry bigger spacecraft. Unfortunately, they cost a lot more to launch.
- **Power:** Every spacecraft needs power in order to function. The more instruments that are onboard, the more power is needed for them to operate. **Solar panels** must be very large, but even so, still do not produce a lot of power. They require a great deal of direct sunlight to operate, so missions with solar panels are limited to being near the Martian equator, and can only operate for about 3 months of the year. **Fuel cells** create power through a chemical reaction much like batteries and produce a moderate amount of power, but they will only function for a limited period of time, generally only a few days or weeks. **Radioisotope power systems** (RPS) produce power from the heat generated by decaying radioactive materials. They produce a lot of power and can operate at any time of year and anywhere on the surface. They are quite heavy, extremely expensive, and require more precautions.
- **Reliability:** Some rockets are more reliable than others.



- **Bottom line:** Engineering constraints often force you to make trade-offs. These constraints may keep you from being able to achieve all of your science goals, so you have to choose the equipment that will allow you to achieve as many of your science goals as possible.

STEP 4: ELABORATE

Apply technological design skills to a novel problem.

A. Choose one of the following:

- Ask students to identify at least 2 engineering constraints from the video and follow up with an explanation of how NASA may have overcome these constraints in the mission. This task should be in individual assignment to determine if students are able to apply their recently acquired knowledge to a new scenario.
- Rerun the simulation, but decrease the budget.
- Research possible landing sites to consider additional engineering constraints.
- Give student groups a copy of the Comparing Two Mars Rover Projects and ask them to reflect on the differences in the design of these Rover missions. What are some of the differences in engineering constraints that must have been overcome for each mission?

STEP 5: EVALUATE

Evaluate change in ability to solve engineering problems.

- #### A. Post-Ideas:
- Ask students to complete the post-ideas. Students will need to refer back to the pre-survey and simulation to respond to these questions.

6.0 Extensions

Choose another activity from Step 4: Elaborate.

7.0 Evaluation/Assessment

Rubric: A rubric has been provided to assess student understanding of the simulation and to assess metacognition. A copy has been provided in the Student Guide for students to reference prior to the simulation. This rubric will allow them to understand the expectations set before them.



8.0 References

- Anderson, L.W., & Krathwohl (Eds.). (2001). *A taxonomy for learning, teaching, and assessing: A revision of Bloom's taxonomy of educational objectives*. New York: Longman.
- Bybee, R., Taylor, J., Gardner, A., Van Scotter, P., Carson Powell, J., Westbrook, A., Landes, N. (2006) *The BSCS 5E instructional model: origins, effectiveness, and applications*. Colorado Springs: BSCS.
- Donovan, S. & Bransford, J. D. (2005). *How Students Learn: History, Mathematics, and Science in the Classroom*. Washington, DC: The National Academies Press.
- Lantz, H.B. (2004). *Rubrics for Assessing Student Achievement in Science Grades K-12*. Thousand Oaks: Corwin Press.
- Miller, Linn, & Gronlund. (2009). *Measurement and assessment in teaching*. Upper Saddle River, NJ: Pearson.
- National Academies Press. (1996, January 1). *National science education standards*. Retrieved February 7, 2011 from http://www.nap.edu/catalog.php?record_id=4962
- National Research Council. (2012). *A framework for K-12 science education: Practices, crosscutting concepts, and core ideas*. Committee on a Conceptual Framework for New K-12 Science Education Standards. Board on Science Education, Division of Behavioral and Social Sciences and Education. Washington, DC: The National Academies Press.
- The Partnership for 21st Century Skills (2011). *A framework for 21st century learning*. Retrieved March 15, 2012 from <http://www.p21.org>